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Agricultural Research Policy Issues

1983 B.Y. Morrison Memorial Lecture

B. Y. Morrison Memorial Lecture

B. Y. Morrison (1891-1966)—a great pioneer in ornamental horticulture and the first director of the United States National Arboretum, Washington, D.C.—showed talent in a wide spectrum of interests during his lifetime. He was a horticulturalist, a landscape architect, a scholar, and a lecturer. Benjamin Morrison did much to advance the science of botany, and he fostered the broad international exchange of ornamental plants.

The Agricultural Research Service (USDA) created the Morrison Lecture series in 1968 to recognize outstanding accomplishments in the agricultural sciences and to stress the urgency of preserving and enhancing man's environment. Over the past 16 years, the Agricultural Research Service has invited a variety of distinguished organizations to cosponsor the lectureship as a special event at their national conventions.

The American Society for Horticultural Science (ASHS), founded in 1903, serves as the professional society for horticulturists and promotes scientific research and education in horticulture within the United States and throughout the world.

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B.Y. Morrison
Memorial Lecture

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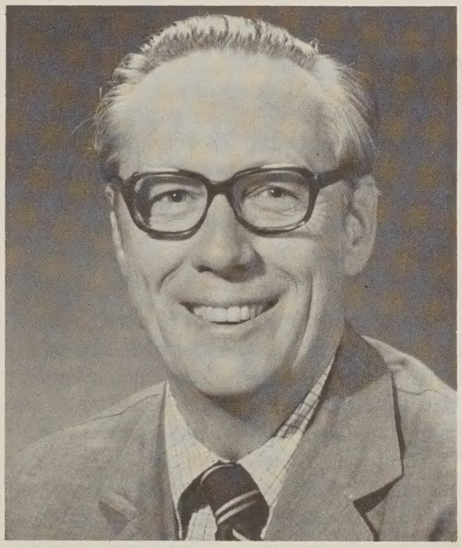
B.Y. MORRISON MEMORIAL LECTURE[1]

Vernon W. Ruttan[2]
Department of Agricultural and Applied Economics and Department of Economics, University of Minnesota, St. Paul, MN 55108

Over the last 50 years, U.S. agriculture has been transformed from a resource-based industry to a science-based industry. It has been transformed from a traditional to a high-technology sector. There are relatively few sectors in the U.S. economy that have been able to maintain their technological leadership. Agriculture is one of those sectors. The future growth of the U.S. economy will depend very heavily on those sectors that are able to maintain their technological leadership—that can continue to generate the dividends resulting from productivity growth. We are part of a world in which scientific and technological leadership in agriculture can no longer be ours by default. Some countries seem more willing than the United States to recognize and to build on complementarity between the public and private sectors. If we are to realize the gains from this complementarity it will place a special burden on each of the 3 major performers of agricultural research—federal, state, and private—to recognize their responsibility for supporting policies that will maintain the strength of the other 2.

Since the mid-1960s, the U.S. federal–state agricultural research system has undergone a series of internal and external reviews. It has been criticized and defended from a variety of scientific, populist, and ideological perspectives. A basic thrust of much of this effort has been to achieve more effective planning and coordination among the several components of the federal–state system. Attempts have also been made to exercise greater federal control over resource allocation in the state system. There have been pressures from the populist front to give greater weight in the research agenda to rural development and to environmental and consumer concerns relative to commodity production; and, there have been pressures from the federal science bureaucracies to substitute competitive grant-funding mechanisms for institutional support in both the federal and the state agricultural research systems.



V.W. Ruttan

I do not attempt, in this paper, to review the proposals and counterproposals that have been put forth for reform of the U.S. agricultural research system in detail. The earlier literature has been reviewed in recent books by Anderson (2), Busch and Lacy (4), Hadwiger (9), and Ruttan (21). The more diligent reader is referred to the massive analysis carried out by the U.S. Office of Technology Assessment (16). Many of the issues have been addressed in the recent Winrock Workshop on Critical Issues in American Agricultural Research (25).

I would like to emphasize several of the agricultural research policy issues that have concerned me as I look to the need to strengthen the U.S. agricultural research system.

I am concerned about the tendency to embrace overly simplistic decision rules for the allocation of responsibility for research between the public and private sectors.

One of these dangerous simplifications is the frequently encountered perception that the public sector should have primary responsibility for basic research and the private sector primary responsibility for applied research.

The perception on which this decision rule is based is the "spillover principle". The spillover principle occupies a highly respected niche in the history of economic thought. The implications that flow from application of the spillover principle to the research enterprise are fairly clear. When the benefits from a research activity are sufficiently pervasive or elusive that they cannot be captured in sufficient amount to enable the organization performing the research to realize a reasonable return on its investment, it is in society's interest to bear the cost of the research (15). The only way that society can realize the benefits is to bear the cost.

The spillover principle is so obviously relevant to much of the activity that is conventionally labeled basic research that it elicites very little dissent from even the most libertarian of political philosophers. It helps explain why those private-sector firms that have broad enough product lines to capture the random fallout from basic research—the Du

[1]The B.Y. Morrison Memorial Lectureship, created in 1968 to recognize outstanding accomplishments in the environmental sciences, is sponsored by the Agricultural Research Service of the U.S. Dept. of Agriculture. The Lectureship commemorates the life and work of the first director of the U.S. National Arboretum. Presented at the 80th Annual Meeting of the American Society for Horticultural Science, McAllen, Texas, on Oct. 18, 1983. The paper draws on material presented at Hearings on Industrial Policy by the Subcommittee on Economic Stabilization of the House Committee on Banking, Finance and Urban Affairs, Aug. 4, 1983; Hearings on Agricultural Research, Subcommittee on Departmental Operations, Research and Foreign Agriculture of the Committee on Agriculture, U.S. House of Representatives, June 28, 1983; the Annual Meeting of the American Association for the Advancement of Science, Detroit, May 27, 1983; and the National Industry–State Agricultural Research Council (NISARC) Conference on Recent Federal and State Policy Initiatives Affective Agricultural Research, Arlington, Va., Oct. 12–13, 1982. The author is indebted to Glenn Fox for assistance in preparing the tables and figures.

[2]Ruttan (BA, Yale Univ.; MA, PhD, Univ. of Chicago) has held academic appointments at Purdue Univ. and Univ. of Minnesota. He has served as President of the Agricultural Development Council (1973–1978) and President of the American Agricultural Economics Association (1971–1972). His research has been on the economics of technical change and agricultural development.

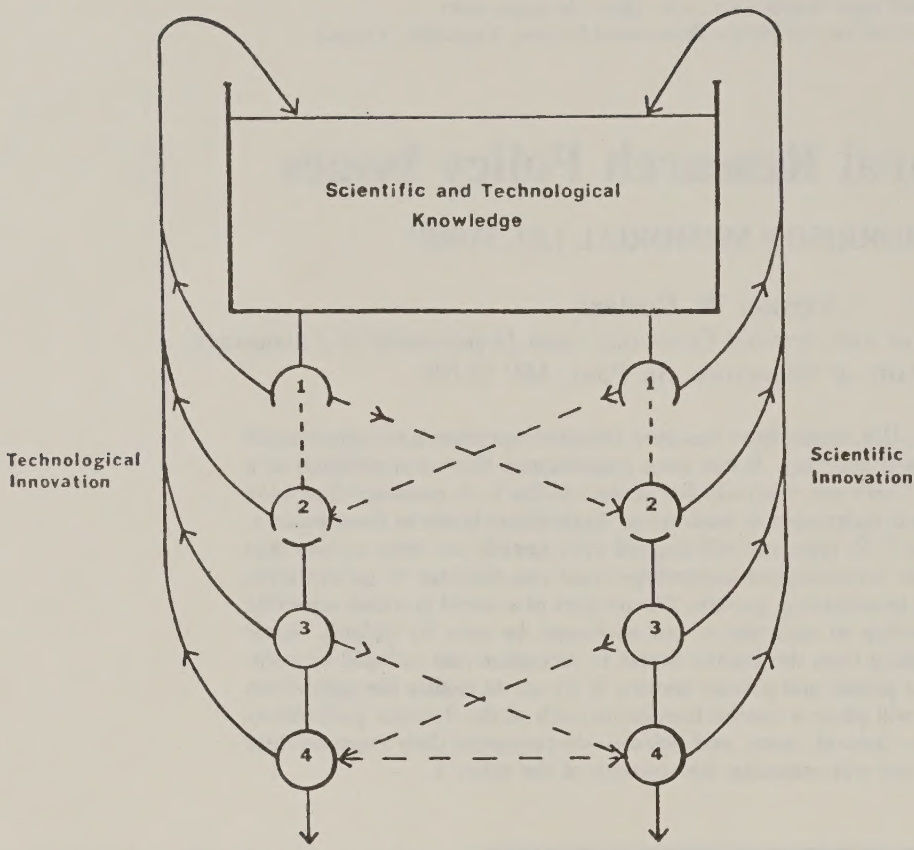


Fig. 1. The interaction between advances in scientific and technical knowledge.

Ponts, General Electrics, IBMs—have been consistently large performers of basic research.

The danger posed by the spillover principle is that its application is so obvious in the case of basic research. Indeed, it is so obvious that there is a temptation to classify any research activity that meets the spillover principle as "basic". But the temptation should serve to remind us that there are broad areas of applied research that meet the test of the spillover principle. For example, much of the agronomic research leading to the design of new production practices, minimum tillage, and other conservation practices will not be done at all unless it is performed by the public sector. We have not yet invented an effective way to package and market the results in a manner that would pay for the cost of the research.

Much of agricultural and industrial research fits an intermediate category. Sufficient gains can be captured to induce a modest level of research expenditure but not enough to induce anywhere near a socially optimum level of research activity. Research in genetics and plant breeding is a useful example. The best available estimates indicate that only about half of the social returns from industrial research and development are captured by the innovating firm (14, 23). I see no reason why these estimates should not apply to industrial research on mechanical technology for agriculture. My guess is that in the area of chemical technology the share of the benefits captured by the innovative firm is somewhat lower than this and in the area of biological technology it may be substantially lower. The result is a substantial underinvestment in agriculturally related research in the private sector. We have not yet designed incentives that induce an efficient level of private research investment.

I am concerned about the need to maintain and to strengthen the articulation between advances in knowledge and technology development and between technology development and improvements in practice.

The productivity of modern agriculture is the result of a remarkable fusion of technology and science. This fusion did not come easily. The advances in cropping practices and tillage equipment in western Europe, from the Middle Ages until well into the 19th century, evolved entirely from husbandry practices and mechanical insights. Lynn White has observed: "Science was traditionally aristocratic, speculative, intellectual in intent; technology was lower class, empirical and action oriented" (24). This cultural distinction persisted in the folklore regarding the priority of basic science over applied science and professional practice (in medicine, engineering, agronomy) long after the interdependence of science, technology, and practice had eliminated the functional and operational value of the distinction.

It is now clear that the basic–applied dichotomy is nowhere near as clear-cut as it appeared to Vannevar Bush and the other architects of post-World War II science policy (5). The orthodox view implies a simple linear relationship between advances in science and technology: "basic science developed theory and understanding; technology took that knowledge and provided blueprints for a change in technology".

As historians of science and technology have begun to examine the processes by which advances in knowledge and technology have actually come about, it has become clear that patterns of interaction tend to be much more complex (Fig. 1). Instead of a single path running from scientific discovery through applied research to development, it is more representative to think of science-oriented and technology-oriented research as 2 parallel but interacting paths that both lead from, and feed back into, advances in scientific and technical knowledge (12, 13). There are also many direct linkages or interactions that occur at the leading edges of advances in both science and technology.

In some cases a single individual or research team may occupy a leading role in advancing both knowledge and technology. An important historical example is the case of William Shockley and his associates in the solid state research group at Bell Laboratories who both advanced the theory of semiconductors and made the initial advances in transistor technology. This pattern was clearly evident in the interaction among George H. Schull (Carnegie Institution), Edward M. East and Donald F. Jones (Connecticut Agricultural Experiment Station), and Paul C. Mangelsdorf (Harvard Univ.) in the development and extension of the theory of hybrid vigor

Table 1. Estimated impacts of research and extension investments in U.S. agriculture (8).

Period and subject	Annual rate of return (%)	Percentage of productivity change realized in the state undertaking the research
1868–1926: All agricultural research	65	not estimated
1929–1950:		
Technology-oriented agricultural research	95	55
Science-oriented agricultural research	110	33
1948–1971:		
Technology-oriented agricultural research		
South	130	67
North	93	43
West	95	67
Science-oriented agricultural research	45	32
Farm management and agricultural extension	110	100

and the invention of the double-cross method of hybrid seed production (3). It also appears to represent a valid interpretation of some of the interrelationships between scientific and technological advances in biotechnology—in molecular genetics and genetic engineering—that are underway at the present time (21, p. 56–58).

As we reform the institutions that fund and perform agricultural research, it is important that we strengthen the articulation between advances in knowledge and technology development. The classic explanation for the lag in technology in the United Kingdom during the interwar and early postwar period was that the U.K. had not solved the problem of linking advances in knowledge with advances in technology—that the U.K. had failed to institutionalize the linkages between discovery and development. The recommendations in the 1971 Rothschild report for the establishment of a customer-contract relationship to direct the activities of the national research councils was partial response to this concern (20).

We are now hearing the same explanation that used to be advanced for lagging productivity growth in the U.K, advanced to explain the dramatic decline in productivity growth in U.S. industry since the late 1960s (19). Although the evidence is not yet conclusive, it is hard for me to escape to the conclusion that the institutional changes introduced to implement national science policy after World War II have contributed to

Table 2. The international agricultural research institutes.[z]

Center	Location	Research	Coverage	Date of initiation	Core budget for 1980 ($000)[y]
IRRI (International Rice Research Institute)	Los Banos, Philippines	Rice under irrigation, multiple cropping systems; upland rice	Worldwide, special emphasis on Asia	1959	16,119
CIMMYT (International Center for the Improvement of Maize and Wheat)	El Batan, Mexico	Wheat (also triticale, barley); maize (also high-altitude sorghum)	Worldwide	1963	17,035
IITA (International Institute of Tropical Agriculture)	Ibadan, Nigeria	Farming systems: cereals (rice and maize as regional relay stations for IRRI and CIMMYT); grain legume (cowpeas, soybeans, lima beans); root and tuber crops (cassava, sweet potatoes, yams)	Worldwide in lowland tropics, special emphasis on Africa	1967	15,106
CIAT (International Centre for Tropical Agriculture)	Palmira, Colombia	Beef; cassava; field beans; swine (minor); maize and rice (regional relay stations to CIMMYT and IRRI)	Worldwide in lowland tropics, special emphasis on Latin America	1968	14,998
WARDA (West African Rice Development Association)	Monrovia, Liberia	Regional cooperative effort in adaptive rice research among 13 nations with IITA and IRRI support	West Africa	1971	2,768
CIP (International Potato Centre)	Lima, Peru	Potatoes (for both tropical and temperate regions)	Worldwide, including linkages with developed countries	1972	8,048
ICRISAT (International Crops Research Institute for the Semi-Arid Tropics)	Hyderabad, India	Sorghum; pearl millet; pigeon peas; chickpeas; farming systems; groundnuts	Worldwide, special emphasis on dry semiarid tropics, nonirrigated farming; special relay stations in Africa under negotiation	1972	12,326
IBPGR (International Board for Plant Genetic Resources)	FAO, Rome	Conservation of plant genetic material with special reference to crops of economic importance	Worldwide	1973	3,124
ILRAD (International Laboratory for Research on Animal Diseases)	Nairobi, Africa	Trypanosoiasis; theileriasis	Mainly Africa	1974	10,443
ILCA (International Livestock Center for Africa)	Addis Ababa, Ethiopia	Livestock production system	Major ecological regions in tropical zones of Africa	1974	8,986
ICARDA (International Centre for Agricultural Research in Dry Areas)	Lebanon and Syria	Crop and mixed farming systems research, with focus on sheep, barley, wheat, broad beans, and lentils	West Asia & north Africa, emphasis on the semiarid winter precipitation zone	1976	11,825
IFPRI (International Food Policy Research Institute)	Washington, D.C.	Food policy	Worldwide	1975	2,400
ISNAR (International Service for National Agricultural Research)	The Hague, Netherlands	Strengthening the capacity of national agricultural research programs	Worldwide	1979	1,199

[z]Source: Crawford, J.G. 1977. Development of the International Agricultural Research System, p. 282–283. In: T.M. Arndt, D.G. Dalrymple, and V.W. Ruttan (eds.). *Resource allocation and productivity in national and international agricultural research*. Univ. of Minnesota Press, Minneapolis.
[y]Budget data for 1980 obtained from the Secretariat for the Consultative Group on International Agricultural Research, World Bank, Washington, D.C.

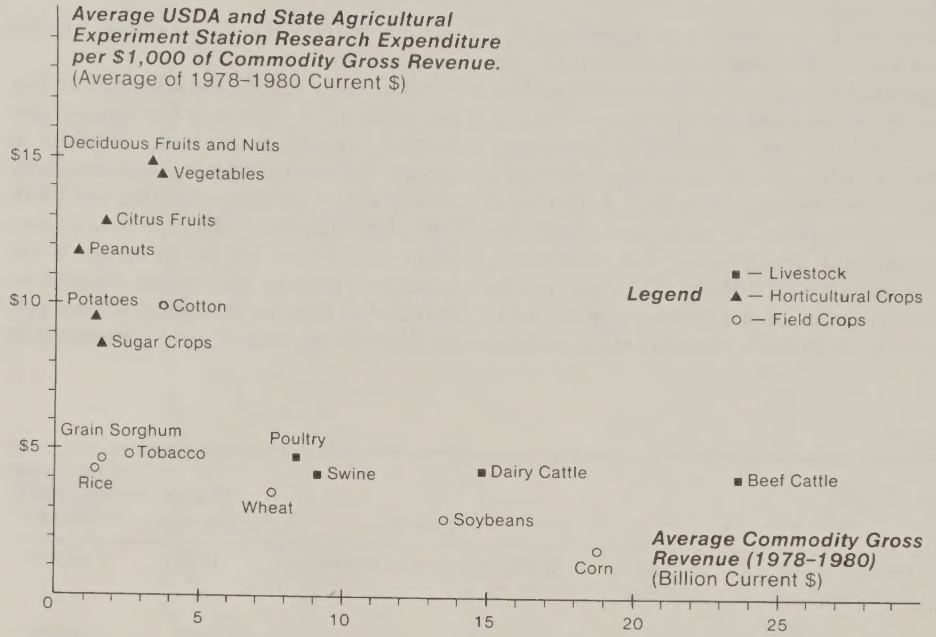


Fig. 2 Average USDA and state agricultural experiment station research expenditures per $1000 of commodity gross revenue.

the disarticulation rather than to the strengthening of the linkages between advances in knowledge and technology development (22). There is a critical need for the architects of national science policy to give attention to the problem of how to institutionalize more effective articulation between advances in knowledge and advances in technology. And we must be particularly careful, in those areas where articulation is effectively institutionalized, that the reforms that are introduced do not lead to further disarticulation.

I am concerned about the ability of the agricultural sector to sustain a rate of productivity growth that approaches the rate that prevailed during the first 3 decades after World War II.

There are several sources of this concern. One is *the growth of maintenance research relative to productivity enhancing research.* Maintenance research is the research needed to offset the forces that would otherwise result in productivity losses, such as the evolution of pests and pathogens or declines in soil fertility and structure. There is a substantial basis for hypothesizing that the research effort needed to maintain existing productivity levels is a positive function of the level of productivity—that maintenance research must be larger when maize yields are at 8 MT/ha than when they were 2 MT/ha. This implies that if research budgets remain relatively static, a larger share of the total budget will be devoted to maintenance research relative to research designed to advance productivity (21, p. 60).

A 2nd reason for concern is *lagging productivity growth in the agricultural input industries.* These are the industries that embody new scientific and technical knowledge in inputs used in agricultural production—new mechanical, chemical, and biological technologies. This concern about the agricultural input industries goes beyond the weakening of productivity growth in manufacturing. There

Table 3. Commodity specific agricultural research expenditure, 1978–1980.[z]

Commodity	Research expenditure (million current $) 1978 USDA	1978 SAES	1978 TOTAL	1979 USDA	1979 SAES	1979 TOTAL	1980 USDA	1980 SAES	1980 TOTAL	Avg research expenditure (million current $) USDA	Avg SAES	Avg TOTAL
Vegetables	14.7	36.4	51.1	15.8	39.6	55.4	15.4	46.7	62.1	15.3	40.9	56.2
Deciduous fruit	13.7	31.6	45.3	14.7	33.7	48.4	13.9	38.9	52.8	14.1	34.7	48.8
Citrus fruit	9.7	11.8	21.5	9.2	12.7	21.9	9.8	13.6	23.4	9.6	12.7	22.3
Potatoes	4.2	8.0	12.2	4.2	8.8	13.0	4.2	9.9	14.1	4.2	8.9	13.1
Sugar crops	6.2	5.1	11.3	7.8	5.0	12.8	7.9	5.4	13.3	7.3	5.2	12.5
Tobacco	5.9	6.2	12.1	4.7	7.0	11.7	4.8	7.9	12.7	5.1	7.0	12.2
Peanuts	3.8	4.3	8.1	3.6	4.5	8.1	3.9	4.9	8.9	3.8	4.6	8.4
Cotton	24.1	11.9	36.0	23.1	12.8	35.9	22.7	15.3	38.0	23.3	13.3	36.6
Rice	2.3	3.5	5.8	2.0	4.0	6.0	2.3	4.6	6.9	2.2	4.0	6.2
Sorghum	2.1	4.7	6.8	2.3	4.9	7.2	2.4	6.7	9.1	2.3	5.4	7.7
Wheat	10.7	12.7	23.4	10.8	14.0	24.8	10.9	17.5	28.4	10.8	14.7	25.5
Soybeans	12.7	20.3	33.0	13.5	22.5	36.0	14.6	28.4	43.0	13.6	23.7	37.3
Corn	11.4	18.3	29.7	12.8	20.6	33.4	12.3	24.7	37.0	12.2	21.2	33.4
Sheep and wool	8.6	8.9	17.5	8.9	9.2	18.1	8.9	11.1	20.0	8.8	9.7	18.5
Poultry	12.8	25.5	38.3	12.6	28.3	40.9	12.3	31.7	43.0	12.6	28.5	40.7
Swine	13.3	21.1	34.4	14.7	24.6	39.3	15.2	29.4	44.6	14.4	25.0	39.4
Dairy cattle	16.3	39.3	55.6	21.7	44.8	66.5	20.0	51.7	71.7	19.3	45.3	64.6
Beef cattle	29.8	56.9	86.7	28.6	64.6	93.2	29.5	75.4	104.9	29.3	65.6	94.9
Subtotal (commodities above)	202.3	326.5	528.8	211.0	361.6	572.6	211.0	423.8	634.8	208.1	370.6	578.7
Other commodities	33.2	67.3	100.5	35.0	74.5	109.4	36.8	87.1	123.9	35.0	76.3	111.3
Not commodity-specific	272.1	255.1	527.3	267.9	282.0	549.9	301.3	342.3	643.5	280.4	293.1	573.6
Total	507.7	648.9	1156.6	513.9	718.1	1231.9	549.1	853.1	1402.3	523.6	740.0	1263.6
Commodity-specific research as a proportion of total (%)	46.4	60.7	54.4	47.9	60.7	55.4	45.1	59.9	54.1	46.5	60.4	54.6

[z]Sources: 1) *Inventory of Agricultural Research FY 1978*, Vol. 2, USDA, Science and Education Administration, Apr. 1981. 2) *Inventory Agricultural Research FY 1979, FY 1980*, USDA, Cooperative State Research Service, Oct. 1982.

Table 4. Commodity gross revenue, 1978–1980.[z]

Commodity	Gross revenue (million current $) 1978	1979	1980	Avg gross revenue[y] (million current $)
Vegetables	3,661	3,950	4,047	3,886
Deciduous fruit	3,034	3,405	3,489	3,309
Citrus fruit	1,594	1,773	1,905	1,757
Potatoes	1,224	1,172	1,979	1,458
Sugar crops	1,133	1,406	2,084	1,541
Tobacco	2,680	2,154	2,720	2,518
Peanuts	834	819	578	744
Cotton	3,045	4,391	3,987	3,808
Rice	1,087	1,384	1,873	1,448
Sorghum	1,464	1,880	1,696	1,680
Wheat	5,281	8,070	9,278	7,543
Soybeans	12,450	14,250	13,560	13,420
Corn	16,281	19,904	20,571	18,919
Sheep and wool	459	501	494	485
Poultry	7,753	8,606	8,850	8,403
Swine	9,066	9,416	8,847	9,110
Dairy cattle	12,957	14,949	16,890	14,932
Beef cattle	19,554	25,994	25,365	23,638
Total	103,557	124,024	128,213	118,598

[z]*Agricultural Statistics, 1982*, USDA, Washington, D.C., 1982.
[y]Calculated as a simple average of 1978, 1979, and 1980 in current dollars.

is also substantial evidence of a decline in productivity in industrial research itself. In the pesticide and animal drug industries, the share of the research budget allocated to defensive research has arisen. And the identification of new chemical entities that eventually are embodied in new products per scientist year is declining (6).

When these considerations are added to a 3rd source for concern, *the lag in public sector research support since the mid-1960s and the more recent slowing of productivity growth indicators* (7), it leads me to anticipate a slower rate of productivity growth in 1980–2000 than in 1950–1980. Even a significant reversal of the lag in research funding can be expected to have little impact on agricultural productivity growth until at least the mid-1990s.

I am concerned about the limited understanding of the implications of the Hatch "formula funding" for state incentives to support agricultural research.

It is becoming increasingly clear from the research productivity studies that a substantial share of the benefits from technology development at the state level spill over into other states (or parts of states) with similar agro-ecological (or geoclimatic environments). And a substantial share of the benefit from research designed to produce new knowledge spills over into other agro-ecological regions. In the United States, in the neighborhood of 50% of the benefits from agricultural research in the typical state are captured by other states (Table 1; also 8, 17). It is hard to escape the conclusion that state legislators take this geographic spillover into account, if only implicitly, in decisions about the level of agricultural research fundings.

Federal funds allocated to the states for support of the state agricultural experiment stations are—except for funds reserved for cooperative regional research efforts and competitive grants—allocated by a formula based on the number of farms and the size of the rural population in each state. Most state legislators provide support for the state experiment stations substantially in excess of the federal matching requirements. It is not unreasonable to view the formula funds as a partial compensation to the individual states for their contribution to economic growth in neighboring states. It also seems clear that the incentive effect would be greater if the formula required the federal government to match state expenditures rather than that the state governments match the federal transfer.

In stressing the importance of institutional support to sustain long-term research efforts, I am not questioning the contribution that an effective competitive grants program can make to the strengthening of agricultural research. Indeed, I consider it important to move the competitive grant funding levels to the $30 million range as soon as possible. A competitive grant system can be an effective instrument to open up innovative areas of research. Arguments about the merits of institutional and project research support should be cast in terms of the relative mix of the 2 types of support rather than the absolute merits of either system. But the productivity of the traditional institutional support system has been high. This places a heavy burden on those who would argue for the substitution of a centralized competitive grant system for the traditional institutional support system to demonstrate that such a shift would substantially enhance the productivity of the research effort or draw substantial new resources into agricultural research (21, p. 231).

I am concerned about what appears to be a decline in the attractiveness of graduate education in the agricultural sciences and in the sciences related to agriculture on the part of American students.

Graduate enrollment in the agricultural sciences, and in the sciences generally, on the part of American students declined in the last half of the 1970s and has continued into the 1980s. The decline has been greater in the science-oriented fields than in the more applied or professional fields. Part of the decline in enrollment by American students has been offset by increases in enrollment by non-U.S. citizens. In many departments, non-U.S. citizens now account for more than half of all graduate students (10).

One implication of these trends is that in another decade students who entered graduate training as non-U.S. citizens will represent a much larger share of graduate research faculty in universities and of research scientists in both public- and private-sector research institutions. In the past, foreign-born and foreign-trained scientists have made ma-

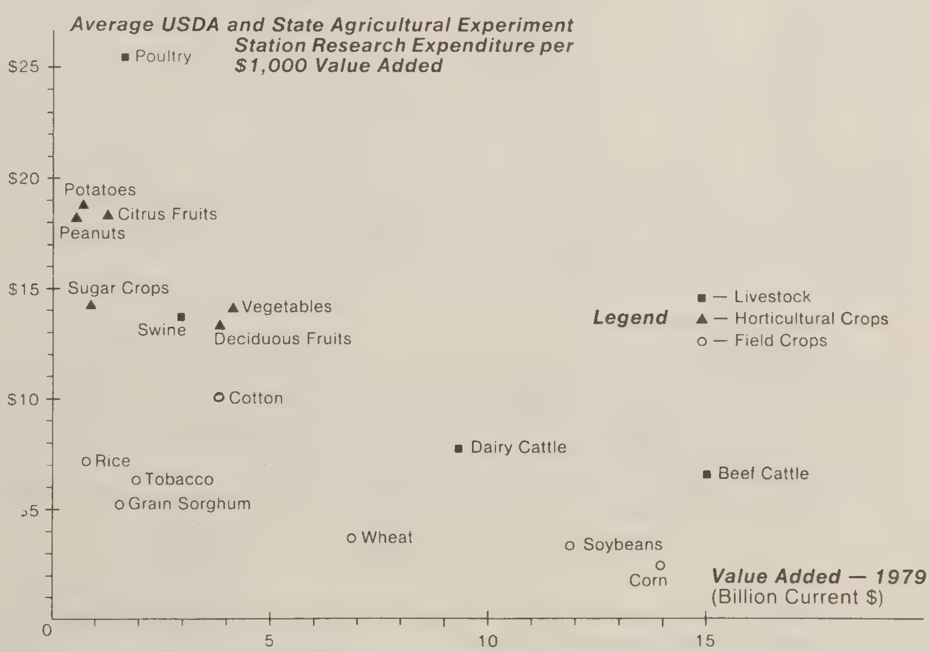


Fig. 3. Average USDA and state agricultural experiment station research expenditures per $1000 of commodity value added.

jor contributions to the advancement of knowledge and the development of technology in the United States. One only has to recall the migration of scientists to the United States from Europe in the 1930s and 1940s. We should welcome growth in the proportion of foreign-born scientists in our laboratories and experiment stations if it is based on the ability of American agricultural research institutions to attract the best graduates in the agricultural and agriculturally related biological and physical sciences. But I would be very worried if the proportion of foreign-born scientists should increase because agricultural research careers become unattractive to the brightest students in our undergraduate programs.

It is doubtful that one can address these issues of the attractiveness of agricultural science effectively without reference to the erosion of the salary structure in the public sector. The erosion has been most severe at the federal level. The lag in federal salaries has resulted not only in the erosion of scientific capacity but also of executive and professional capacity throughout the federal government. I must admit to being surprised that the authors of the Winrock Workshop report on "Critical Issues in American Agricultural Research" (25) were able to address the question of strengthening the federal agricultural research system without addressing the issue of salary level and structure. At present, the primary factor that holds a first-rate federal scientist within the system beyond the midcareer is his or her stake in the federal retirement system. And the federal

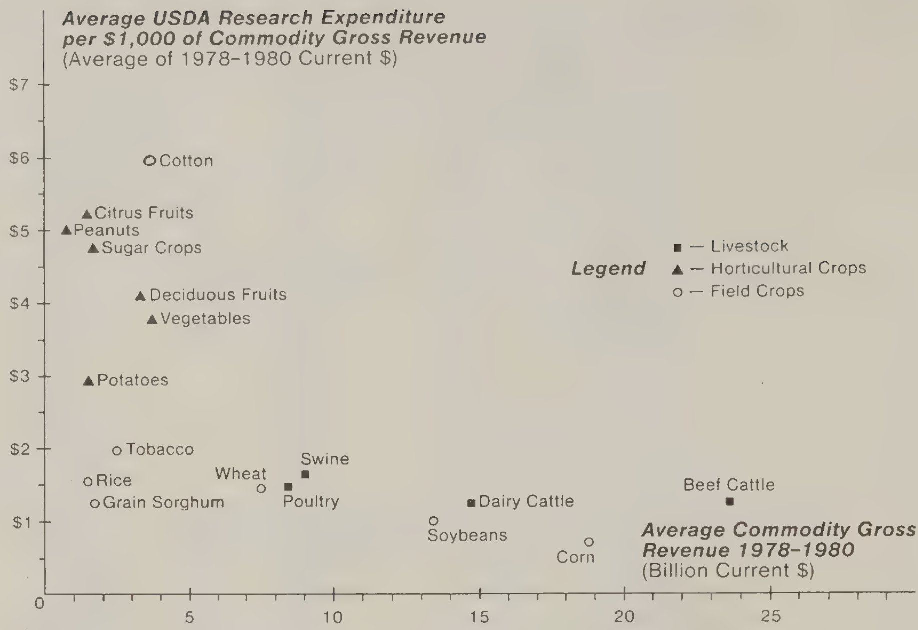


Fig. 4. Average USDA research expenditures per $1000 of commodity gross revenue.

Table 5. Congruence ratios and average research expenditures per $1000 commodity gross revenue.[z]

	Congruence ratios[y]									Avg (1978–1980)					
	1978			1979			1980			Congruence ratio			Research expenditures per $1000 gross revenue		
Commodity	USDA	SAES[x]	TOTAL	USDA	SAES	TOTAL	USDA	SAES	TOTAL	USDA	SAES	TOTAL	USDA	SAES	TOTAL
Vegetables	2.05	3.15	2.73	2.35	3.44	3.04	2.30	3.49	3.10	2.23	3.36	2.96	3.95	10.52	14.47
Deciduous fruit	2.31	3.30	2.98	2.54	3.39	3.08	2.42	3.37	3.06	2.42	3.35	3.04	4.28	10.49	14.87
Citrus fruit	3.11	2.35	2.69	3.05	2.46	2.68	3.13	2.16	2.48	3.10	2.32	2.62	5.49	7.26	12.81
Potatoes	1.76	2.07	1.99	2.11	2.57	2.40	1.29	1.51	1.44	1.72	2.05	1.94	3.04	6.42	9.49
Sugar crops[w]	2.80	1.43	1.99	3.26	1.22	1.97	2.30	0.78	1.29	2.79	1.14	1.75	4.94	3.57	8.56
Tobacco	1.13	0.73	0.90	1.28	1.11	1.18	1.07	0.88	0.94	1.16	0.91	1.01	2.05	2.85	4.94
Peanuts	2.33	1.66	1.94	2.58	1.88	2.14	4.10	2.57	3.11	3.00	2.04	2.40	5.31	6.39	11.74
Cotton	4.05	1.24	2.36	3.09	1.00	1.77	3.46	1.16	1.93	3.53	1.13	2.02	6.23	3.54	9.89
Rice	1.08	1.02	1.06	0.85	0.99	0.94	0.75	0.74	0.75	0.89	0.92	0.92	1.58	2.89	4.50
Sorghum	0.73	1.02	0.93	0.72	0.89	0.83	0.86	1.20	1.08	0.77	1.04	0.95	1.36	3.26	4.65
Wheat	1.04	0.76	0.88	0.79	0.59	0.67	0.71	0.57	0.62	0.85	0.64	0.72	1.50	2.00	3.52
Soybeans	0.52	0.52	0.53	0.56	0.54	0.55	0.64	0.63	0.64	0.57	0.56	0.57	1.01	1.75	2.79
Corn	0.36	0.36	0.36	0.38	0.35	0.36	0.36	0.36	0.36	0.37	0.36	0.36	0.65	1.13	1.76
Sheep and wool	9.59	6.15	7.60	10.44	6.30	7.82	10.95	6.80	8.18	10.34	6.42	7.87	18.30	20.09	38.58
Poultry[v]	0.84	1.04	0.98	0.86	1.13	1.03	0.84	1.08	0.98	0.85	1.08	1.00	1.50	3.38	4.89
Swine	0.75	0.74	0.75	0.92	0.87	0.90	1.04	1.01	1.02	0.90	0.87	0.89	1.59	2.72	4.35
Dairy cattle	0.64	0.96	0.86	0.85	1.03	0.96	0.72	0.93	0.86	0.74	0.97	0.89	1.31	3.04	4.35
Beef cattle	0.78	0.92	0.88	0.65	0.85	0.78	0.71	0.90	0.84	0.71	0.89	0.83	1.27	2.79	4.06
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.77	3.13	4.89
Research expenditure per $1000 gross revenue	1.95	3.15	5.11	1.70	2.92	4.62	1.65	3.31	4.95				1.77	3.13	4.89

[z]Sources: 1) *Inventory of Agricultural Research FY 1978*, Vol. 2, USDA, Science and Education Administration, Apr. 1981. 2) *Inventory of Agricultural Research FY 1979, FY 1980*, USDA, Cooperative State Research Service, Oct. 1982. 3) *Agricultural Statistics 1982*, USDA, Washington, D.C., 1982.

[y]Computed as dollars of research expenditure per $100 of total revenue for each commodity divided by the average research expenditure per $100 of total revenue. That is:

$$CR_t^i = \frac{RE_t^i}{TR_t^i} / \left[\frac{\sum_i RE_t^i}{\sum TR_t^i}\right],$$

where CR_t^i is the congruence ratio for commodity i in year t, RE is research expenditure, and TR is total revenue.

[x]State Agricultural Experiment Stations.

[w]Includes beets and cane.

[v]Includes eggs, turkeys, and chickens.

system is clearly not in a position to bid effectively against either the state system or the private sector for first-rate agricultural scientists or research managers.

I am concerned about the erosion of scientific leadership in federal agricultural research.

My concern includes both scientific leadership and leadership in technology development and programming. This concern does not reflect a lack of confidence in the scientific excellence of the universities or the commitment to technology development and introduction by the private sector. But, neither the universities nor the private sector are capable of providing national program leadership. Fragmentation along institutional and disciplinary lines at the university levels and the pressures arising out of marketing considerations in the private sector preclude such leadership.

Nor is the federal agricultural research system in a position to exercise such leadership. It neither has the scientific capacity nor the bureaucratic structure that it would take to exercise such leadership. But it is the only organization that has the potential capacity for national leadership. I wonder whether today, for example, if it would be possible to mobilize the scientific effort, the technology development, and the field organization that it took to put the screw worm eradication effort into place (18, p. 97–126).

In the past, each of the 3 major performers of agricultural research—federal research, state research, and private research—could assume the effectiveness of the other 2. In such an environment, the rivalry between the state experiment stations and the federal system over budgets and between the public and private sectors over their appropriate roles was not too unhealthy. But we are now in a different world. Any opportunity to strengthen one element in the system must be eagerly embraced and supported by the other agricultural research performers if we are to avoid erosion of the strength of the total system. If the federal system continues to weaken it will weaken the total system.

I am concerned about inadequate articulation among the agricultural research systems in the developed countries.

During the last decade and a half, we have seen the emergence of a new system of international agricultural research institutes in the tropics. This system consists of 10 research institutes and 3 programs (Table 2). It is funded by the Consultative Group for International Agricultural Research (CGIAR) with a general secretariat located at the World Bank and a Technical Advisory Committee (TAC) secretariat located at the Food and Agriculture Organization (FAO) in Rome. Each institute is incorporated separately and has an independent governing board (21, p. 116–146).

The new international system has evolved a highly effective set of institutional linkages with national research systems. It performs an important role in facilitating communication of scientific information, technical knowledge, and genetic material among the national research systems in developing countries. The effectiveness of researchers at remote stations in countries with weak agricultural research systems is greatly enhanced by the international system. For example, the research team at the Mopti rice station in Mali has access, through the West African Rice Development Association (WARDA), to the world collection of rice germ plasm at the International Rice Research Institute in the Philippines and to a communication network that makes the methods and results of rice research throughout the world available to them.

The linkage between the international research system and the national research system in the developed countries is primarily through the bilateral development assistance agencies (the U.S. Agency for International Development and the Canadian International Development and Research Centre, for example) rather than directly to the national research agencies in the developed countries. And there is no comparable institution or set of institutions that provides similar linkages among the national research institutions, or even the research institutions of neighboring provinces or states (between Ontario and Ohio or Michigan, for example) of the developed countries.

The productivity of the U.S. agricultural research system since World War II has, in my judgment, induced a sense of complacency about the gains that might be realized by closer collaborations among the research systems of the developed countries. While the number of scientists in the U.S. system has remained static since the mid-1960s, the number of scientists in national agricultural research systems in Western Europe, Japan, and the U.S.S.R., have experienced substantial growth (8).

There is inadequate effort on the part of the U.S. agricultural research system to a) monitor the progress of agricultural research, b) support participation in scientific meetings, or c) engage in systematic exchange of scientific staff with the agricultural research institutions in other developed countries. These efforts vary greatly among commodity areas. They are perhaps strongest in the area of wheat breeding. But in most commodity areas such exchanges appear to be much less well-organized.

Table 6. Value added in U.S. agriculture and research expenditure per $1000 value added for selected commodities, 1979.[z]

Commodity	Value added (million current $)	Value added as % of total revenue[y]	Research expenditure per $1000 value added (1979)		
			USDA	SAES	Total
Vegetable[x]	3,957	89.1	3.99	10.01	14.00
Deciduous fruit[w]	3,586	75.6	4.10	9.40	13.50
Citrus fruit[v]	1,225	66.5	7.51	10.37	17.88
Potatoes	703	58.4	6.04	12.47	18.51
Sugar crops[u]	908	74.9	8.60	5.55	14.15
Tobacco	1,859	85.4	2.51	3.75	6.26
Peanuts	444	54.1	8.18	10.09	18.27
Cotton	3,514	68.9	6.57	3.63	10.20
Rice	849	61.3	2.38	4.67	7.05
Sorghum[t]	1,418	71.3	1.63	3.45	5.08
Wheat	6,408	78.8	1.69	2.19	3.88
Soybeans	11,237	80.0	1.20	2.00	3.20
Corn	13,204	64.4	0.97	1.56	2.53
Sheep and wool[s]	315	75.2	28.39	29.06	57.45
Poultry[r]	1,628	18.6	7.74	17.36	25.10
Swine	2,834	30.0	5.20	8.67	13.87
Dairy cattle[q]	8,686	58.1	2.49	5.15	7.64
Beef cattle[p]	14,358	54.7	1.99	4.50	6.49

[z]Sources: 1) Kunz, J.J. and J.C. Purcell. 1982. Value added (created) in United States agriculture. Interregional Cooperation Publication of the State Agricultural Experiment Stations, IR-6 Office, Suite 101, Commonwealth Building, 1300 Wilson Boulevard, Rosslyn, VA 22209. (IR-6 Information Report 61). 2) *Inventory of Agricultural Research FY 1979, FY 1980*, USDA, Cooperative State Research Service, Oct. 1982.

[y]From Kunz and Purcell.

[x]The value added total includes tomatoes, lettuce, dry edible beans, onions, sweet corn, mushrooms, cucumbers, celery, cabbage, carrots, snap beans, sweet potatoes, broccoli, asparagus, green peppers, green peas, cauliflower, spinach, garlic, green lima beans, escarole/endive, mint, dry edible peas, eggplant, beets, and artichokes.

[w]The value added total includes apples, grapes, almonds, peaches, strawberries, cherries, pears, prunes and plums, muskmelons, walnuts, avocadoes, pecans, watermelon, cranberries, hops, blueberries, apricots, honeydew melons, nectarines, olives, red raspberries, figs, pistachios, filberts, dates, and blackberries.

[v]The value added total includes oranges, grapefruit, lemons, tangerines, temples, limes, and tangelos.

[u]Includes beets and cane.

[t]Includes grain sorghum.

[s]Includes sheep, lambs, and wool.

[r]Includes eggs, turkeys, and chickens.

[q]Corresponds to the "milk" category in Kunz and Purcell.

[p]Corresponds to the "cattle and calves" category of Kunz and Purcell.

I am concerned about our continuing inability to bring information and analytical capacity from the natural and social sciences to bear on research resource allocation decision processes.

The issue of research resource allocation and planning is one that often generates a strong emotional response on the part of both research scientists and managers. This response is frequently induced by concern about who will have the authority for research planning. In spite of these concerns, central management and planning staffs have been mandated by the legislative and budget agencies responsible for allocating resources to research. Central management and planning staffs have been strengthened in most national agricultural research systems.

The planning staffs and administrators responsible for research resource allocation have not found it easy to respond to the expectations that their efforts would contribute to greater efficiency in the use of research resources or to greater relevance in research resource allocation. They have been pressed to respond to a succession of styles in analysis and planning: project and priority weighting or scoring of research objectives in the mid-1960s, program planning and budgeting in the late 1960s, systems analysis and simulation in the early 1970s, and the rhetoric of technology assessment in the mid-1970s. By the late 1970s, the program planning and budgeting methodology, which had temporarily fallen into disrepute as a result of the gap between promise and performance, had been resurrected under the rubric of zero-based budgeting.

As research-planning staffs have struggled with the demands placed on them, it has become increasingly obvious that effective research planning requires close collaboration among natural and social scientists. This is because *any research resource allocation system, regardless of how intuitive or how formal, cannot avoid making judgments about 2 major questions.*

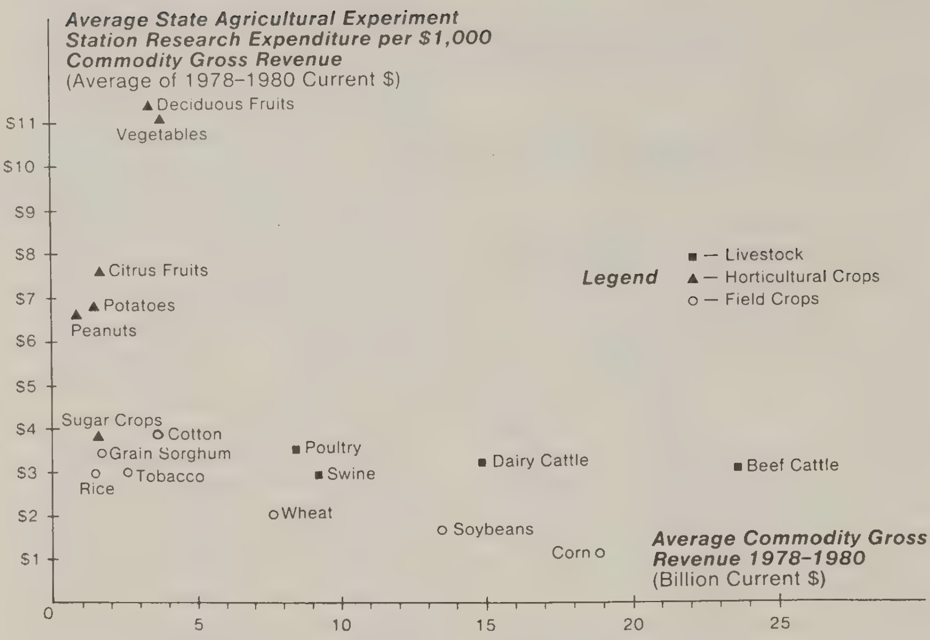


Fig. 6. Average state agricultural experiment station research expenditures per $1000 of commodity gross revenue.

The first question is: *what are the possibilities of advancing knowledge or technology if resources are allocated to research on a particular commodity, a particular resource problem, or a particular disciplinary or scientific field?* If, for example, resources are allocated to the transfer, development, or enhancement of nitrogen-fixing capacity to grasses, what is the probability of success? The answer to such questions can only be provided with any degree of authority by scientists who are on the leading edge of the research discipline or problem being considered. The intuitive judgments of research administrators, even those who were formerly scientists, or research planners and economists must be discounted severely in attempting to answer such questions.

The 2nd question is: *what will be the value to society of the new knowledge or the new technology if the research effort is successful?* If efforts to develop nitrogen-fixing capacity in maize are successful, for example, will it become an efficient source of plant nutrition when evaluated in relation to the economic and environmental costs and returns to other forms of fertility enhancement? The answers to such questions require the use of formal economic and other social science analysis. The intuitive insights of research scientists and administrators are no more reliable in answering questions of value than the intuitive insights of economists and planners in evaluating scientific and technical potential.

Yet the planning of research resource allocation remains largely intuitive. Formal methods have been tested and largely rejected (21, p. 275–294). The new 6-year research plan prepared by the USDA Agricultural Research Service drew on very little analytical capacity in making judgments about the value of alternative research priorities (1). The research resource allocation decisions at the state experiment stations are made primarily at the department—rather than the experiment station—level.

The research resource allocation model implicit in the questions that commonly are raised by both scientists and administrators has been called the parity or the congruence model. The question that is usually asked in the application of the parity or congruence model is how do research expenditures by commodity compare to the relative economic importance of a particular commodity. Does the expenditure of $13 per $1000 of sales in the case of potatoes and less than $3 per dollar of sales in the case of soybeans represent an efficient allocation of research resources? (Fig. 2–7).

One implicit assumption of the parity or congruence model of research resource allocation is that the benefits from research are proportional to the size of the research budget

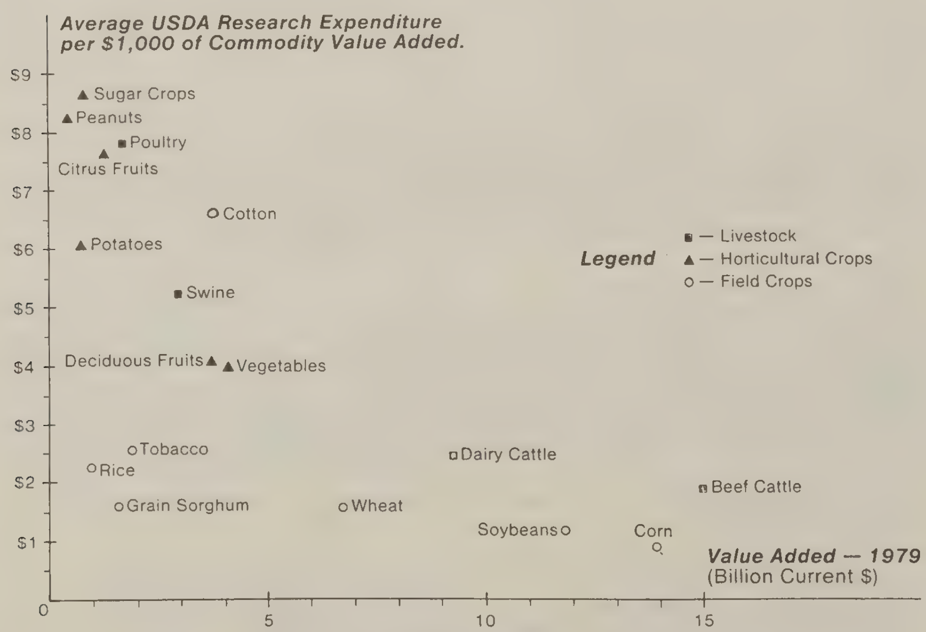


Fig. 5. Average USDA research expenditures per $1000 of commodity value added.

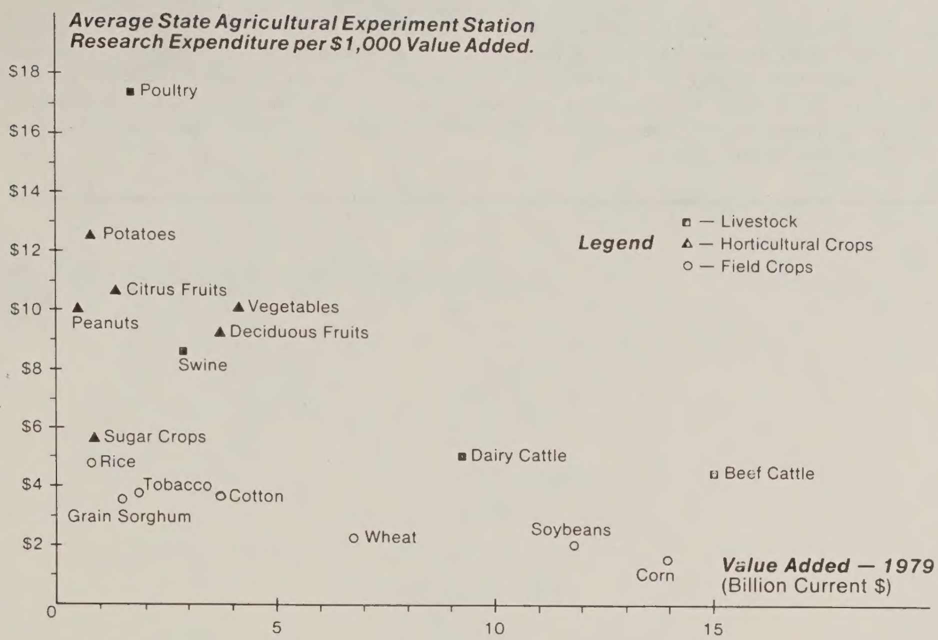


Fig. 7. Average state agricultural experiment station research expenditures per $1000 of commodity value added.

relative to the economic importance of the commodity sector, resource input, or field of science to which the research effort is directed. A 2nd assumption is that the opportunities for productive scientific or technical effort are equivalent in each area of commodity, resource, or disciplinary research activity. Both assumptions are clearly naive. No one believes that either assumption is valid.

In the absence of specific knowledge of research opportunities and payoffs, application of the parity or congruence model may not be entirely inappropriate. But whether one accepts the model as a primary criterion for the allocation of research resources or as a point of departure for the fine-tuning of research budgets, a research manager can hardly begin to make useful allocation decisions in the absence of at least the following congruence calculations:

- A comparison of the ratio of research expenditure by commodity to the value added to national product by each commodity.
- A comparison of the ratio of research expenditure by factor (or resource input) to the cost or economic value of the factor in production.
- A comparison of the ratio of research expenditure to the value added at each stage in the food production chain from purchased inputs to the consumer.

The compilation of a set of research parity or congruence accounts does not imply that resources should be allocated by the parity or congruence model. It does suggest that an explicit rationale should be developed for any departures from the parity rule. When departures are observed, there should be a reason. There should be a reason why our public research system pursues research on peanuts more than 4 times as intensively and on wool more than 15 times as intensively as on wheat. Is it because a dollar saved on wool imports is 15 times as valuable as a dollar earned from wheat exports?

But if the parity rule is inadequate, where can one look for more adequate criteria for research resource allocation? I have reviewed the several formal methodologies in considerable detail (21, p. 267–294). In my judgment, the formal analytical approaches represent useful methodologies for refining the judgements of research scientists and administrators. But they divert too many resources from the practice of science when implemented on a regular basis. And they have great difficulty in achieving compatibility between decision-making at the individual scientist or scientific team level and decision-making at the research system level.

Increasingly powerful methodologies are, however, becoming available to the directors of individual research programs, research institutes, and experiment stations for interpreting scientific, technical, and economic information in a manner that can increase the effectiveness of research efforts, whether evaluated in terms of advances in knowledge or technology. To have access to these methodologies, resources must be devoted to interdisciplinary experimental and systems modeling research in areas described by rubrics such as yield constraint and crop loss modeling, plant growth modeling, and selection indexes.

The major advantage of these methodologies is that they can be carried out as an integral component of ongoing research programs. Their results become directly available to individual scientists and research teams. The results can be fed back immediately into research planning and design. And the results can also be fed forward to the central research management and budgetary units. These methodologies add precision to decentralized research decision-making where the relationship between knowledge generation and decision-making is most fully informed. They are not dependent on implementation by central research planning staffs.

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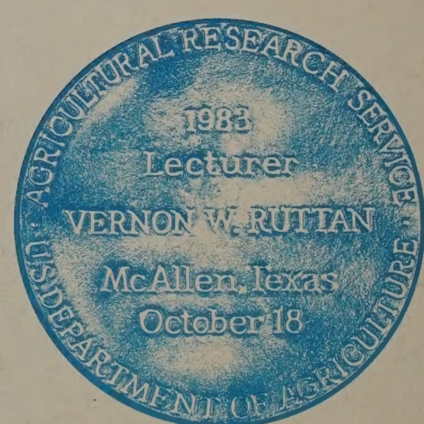
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